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MEMORANDUM FOR IN-HOUSE PUBLICATIONS

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C.W. Beckman, R.L. Geisler "The History of the BATES Motor at RPL
" **AIAA slides** **(Statement A)**

THE HISTORY OF THE BATES MOTOR AT RPL

CHARLES W. BECKMAN
AIR FORCE RESEARCH LABORATORY
ROBERT L. GEISLER
GEISLER ENTERPRISES

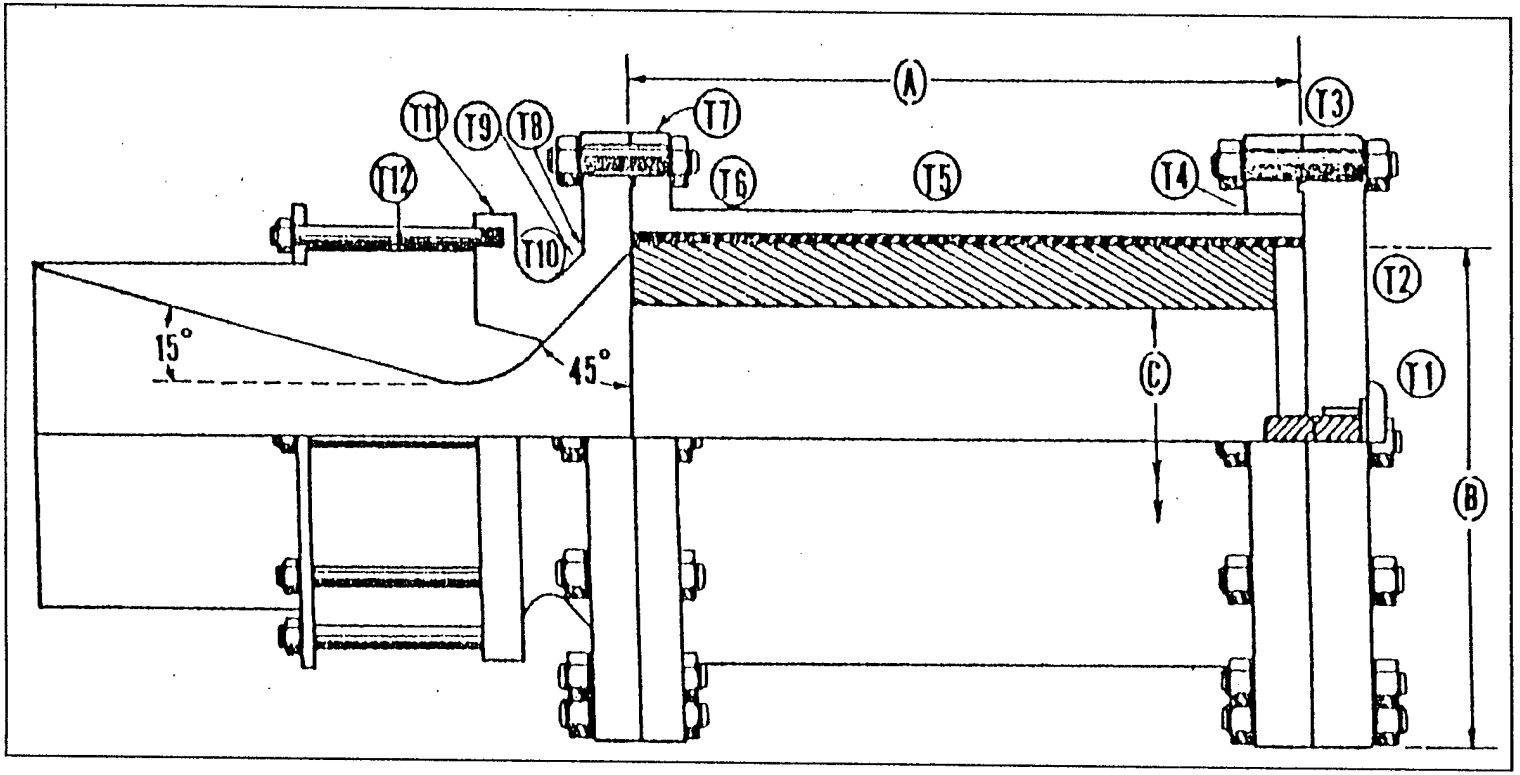
INITIAL BATES FIRING - Sept 1961

BATES

BAllistic Test Evaluation and Scaling

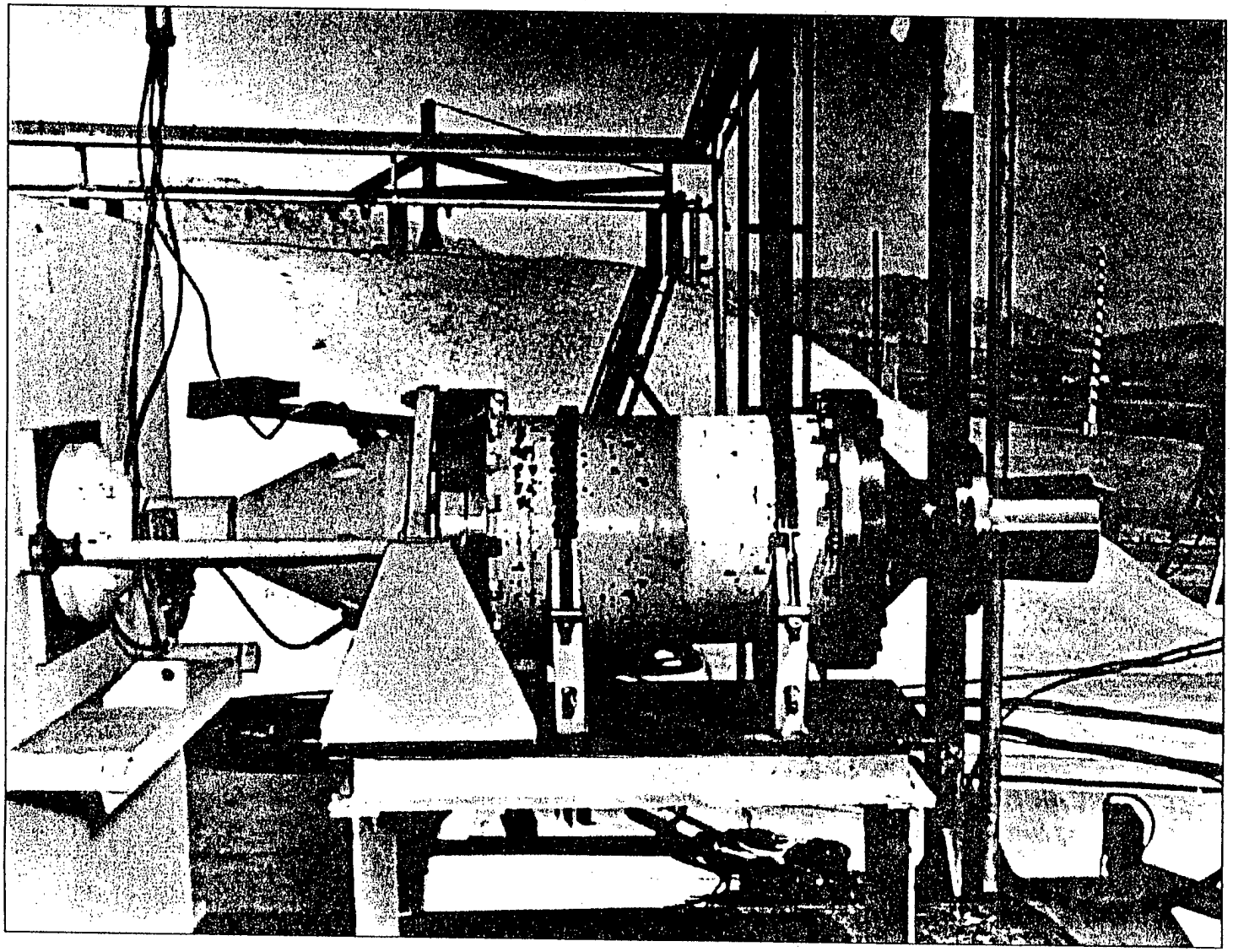
A highly accurate test motor system for ballistic prediction, assessment and comparison.

15-lb and 70-lb BATES Motor Design

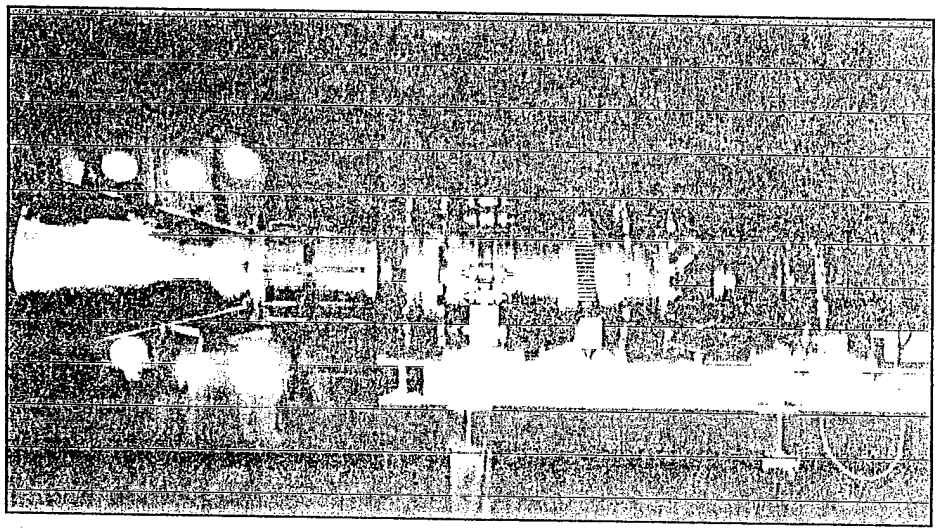


Motor size	15-pound	70-pound
Pressure (psi)	1000.	1000.
Nozzle Diameter (UNITS?)	1.	2.
Gas Residence Time (msec)	8.	17.
Grain Length (in) (A)	12.	20.
Grain Outside Diameter (in) (B)	6.75	12.
Grain Port Diameter (in) (C)	4.6	8.

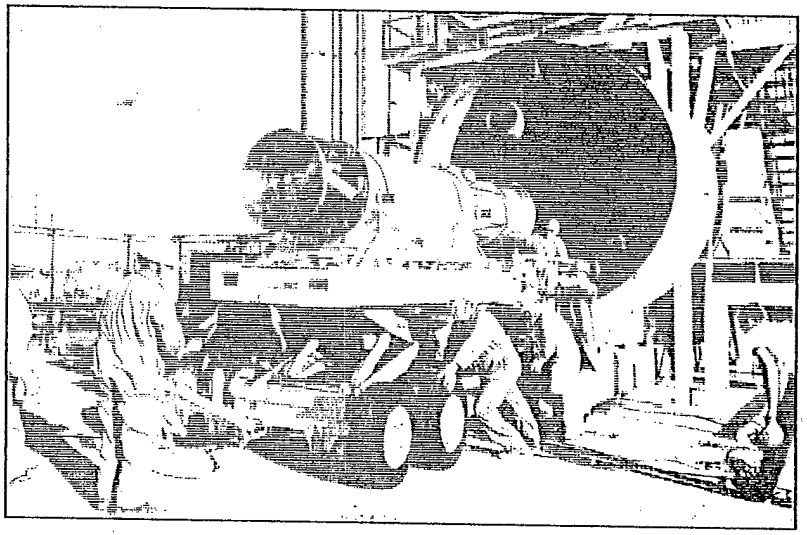
Standard 70-lb BATES Motor



Vacuum Ballistics Testing

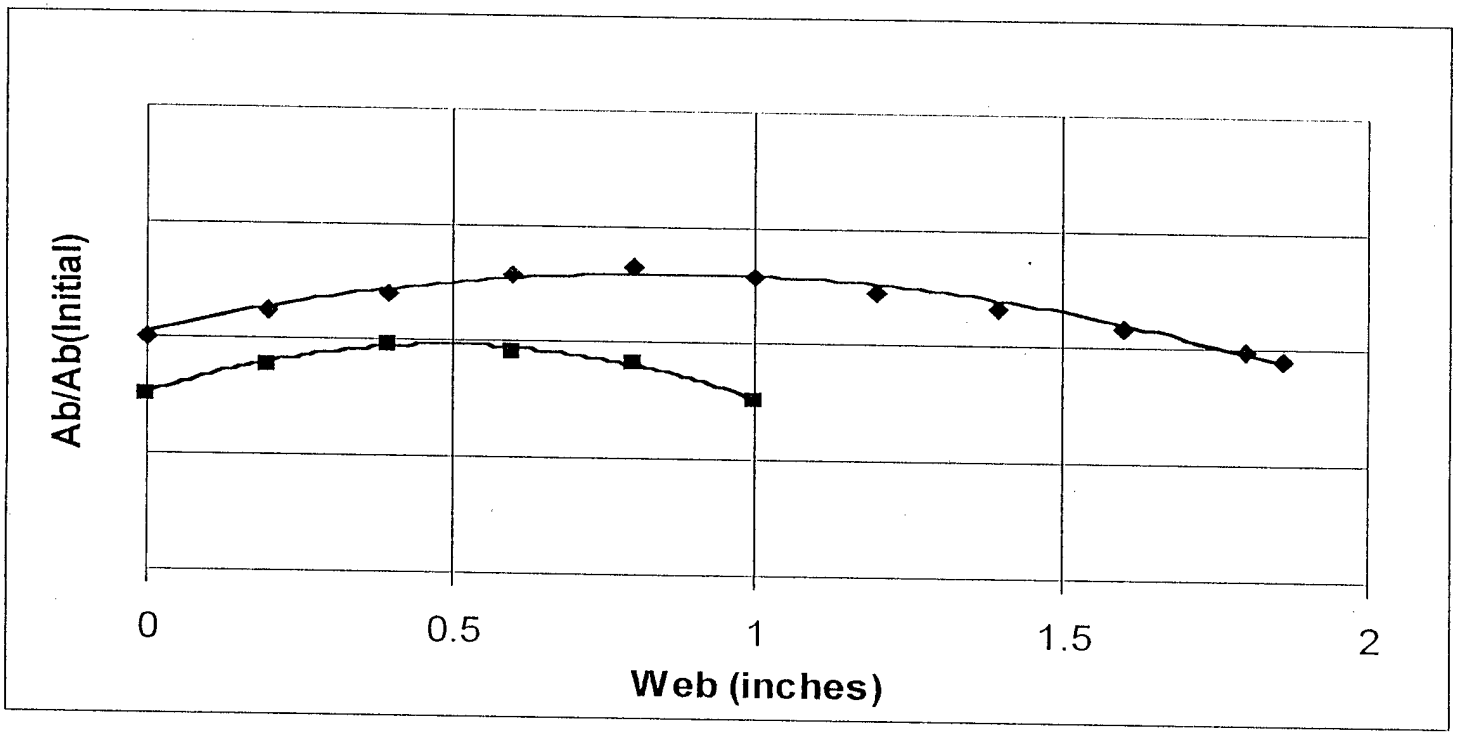


70 Pound Reusable
BATES Motor



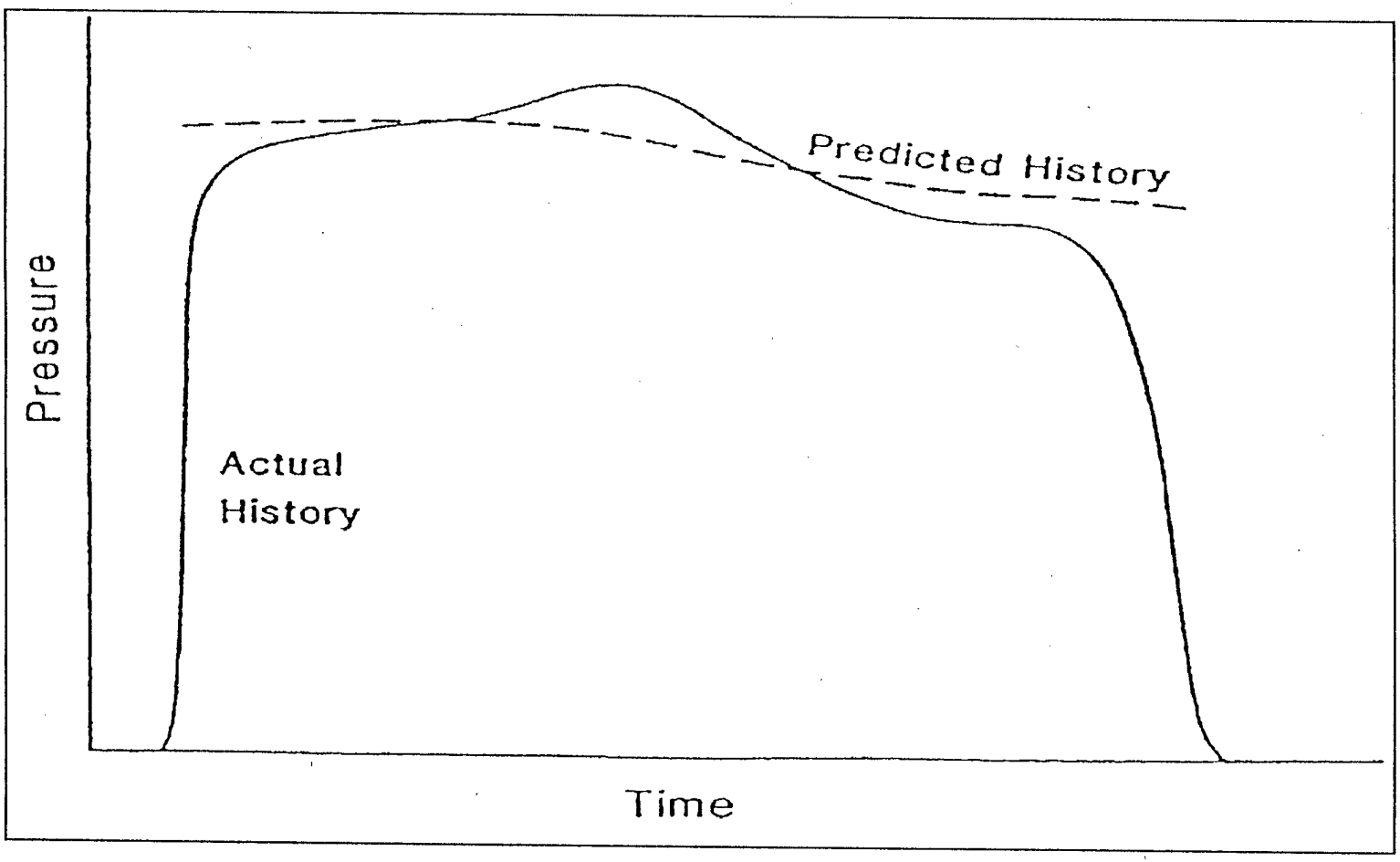
Super BATES Reusable
Motor

15-lb and 70-lb BATES Burnback History



Motor size	15-pound/70-pound
Neutrality (max/ave/min)	1.01/1.00/0.97
Port/Throat Ratio	~30

Ballistic Anomaly Phenomena



BATES DELIVERED SPECIFIC IMPULSE

ESTIMATED ERROR

+ 0.25 seconds

  70-pound thrust accuracy + 0.10 %

  15-pound thrust accuracy + 0.25 %

  3 70-pound firings required for this precision

  6 15-pound firings required for this precision

+ 0.10 seconds

  6 70-pound firings required for this precision

  9 15-pound firings required for this precision

BATES Test History

Motor Firings

Approximately 4000 test firings

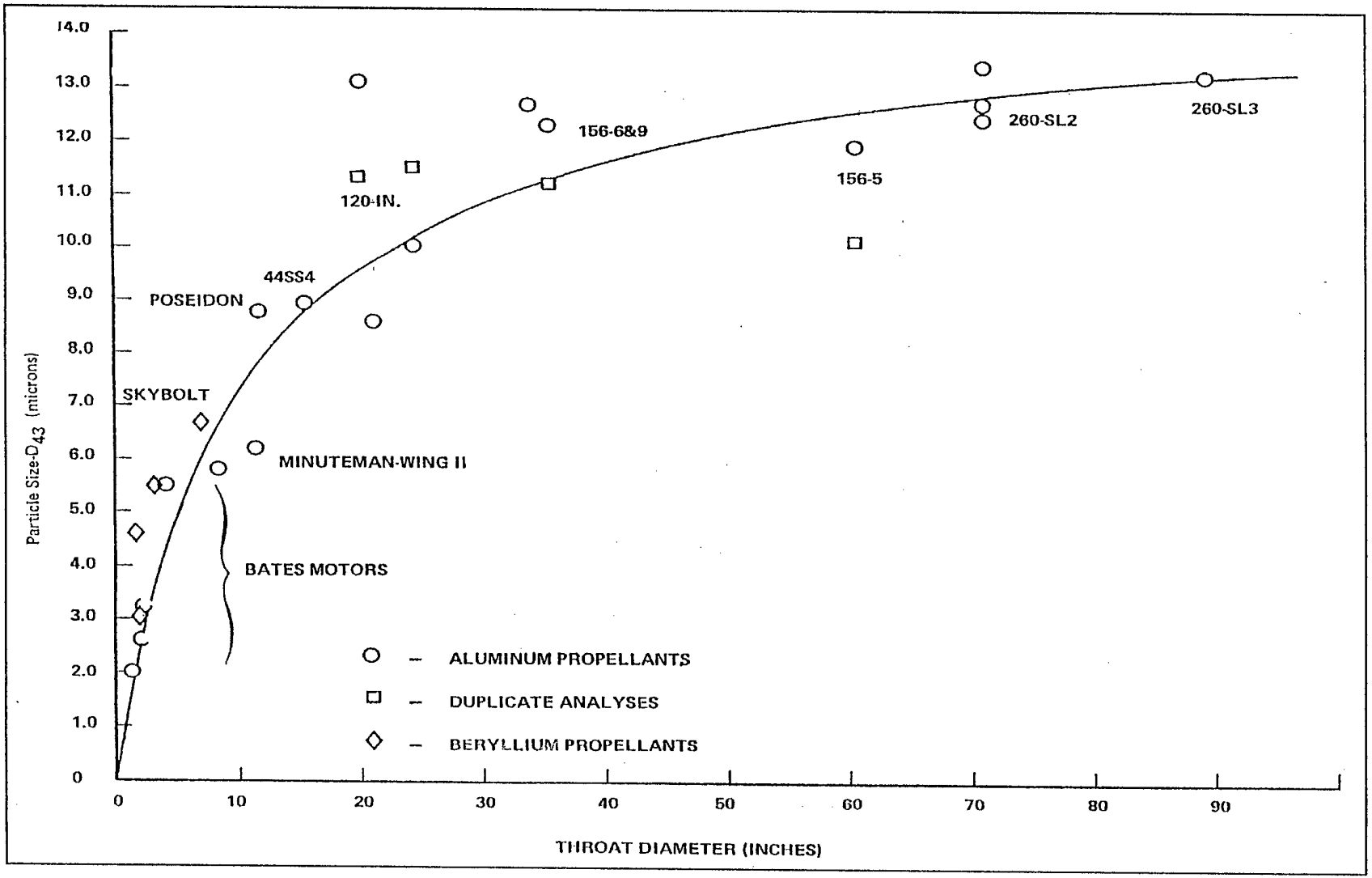
Propellant Evaluations

Approximately 400 formulations evaluated

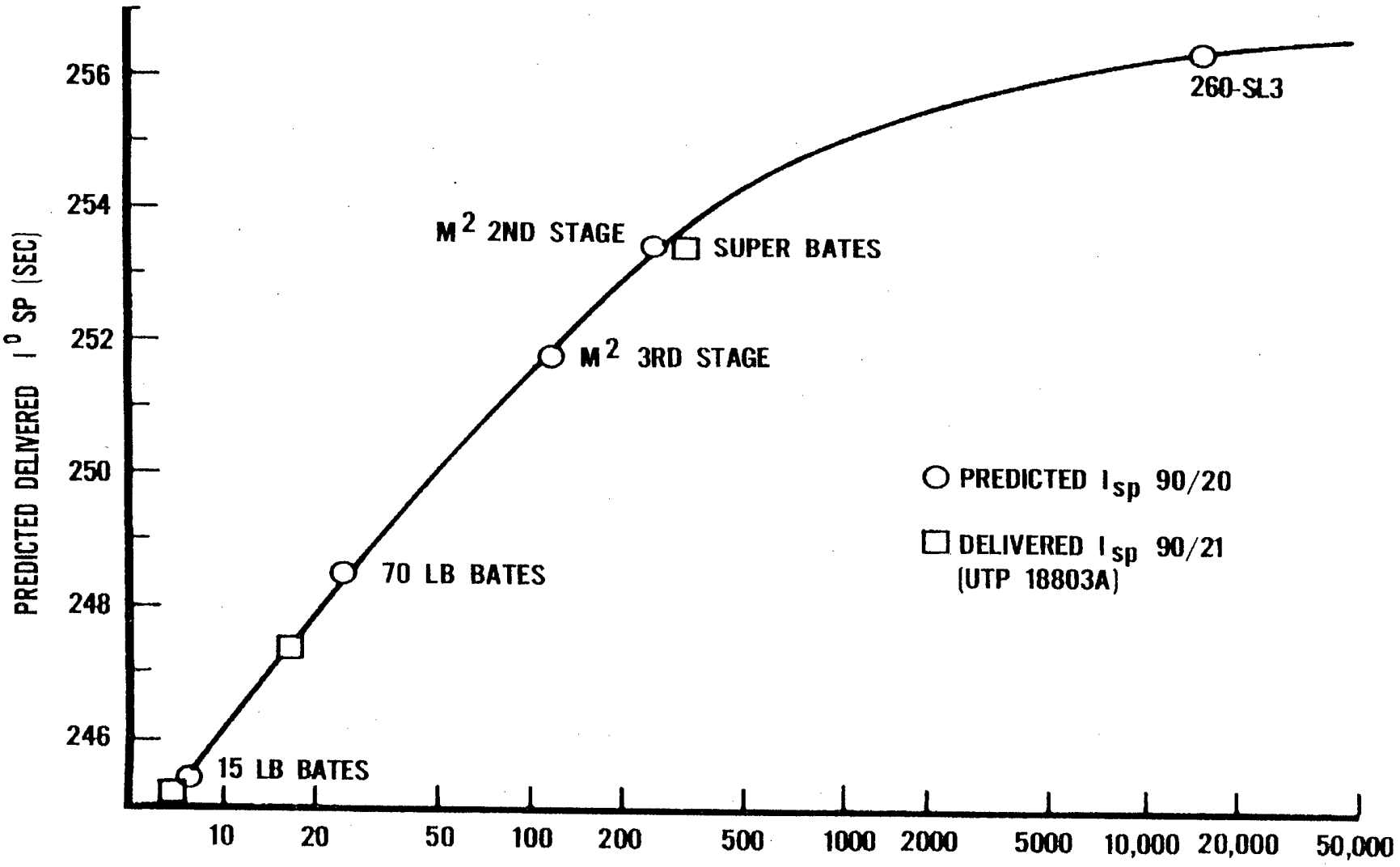
SPECIFIC IMPULSE EFFICIENCY INFLUENCES

- COMBUSTION EFFICIENCY
- HEAT LOSS
- DIVERGENCE LOSSES
- TWO-PHASE FLOW LOSSES
  - MULTIPHASE MOMENTUM LOSSES
  - MULTIPHASE TEMPERATURE NON-EQUILIBRUM
- CHEMICAL RECOMBINATION LOSSES
- FRICTIONAL LOSSES

Particle Size vs Throat Diameter



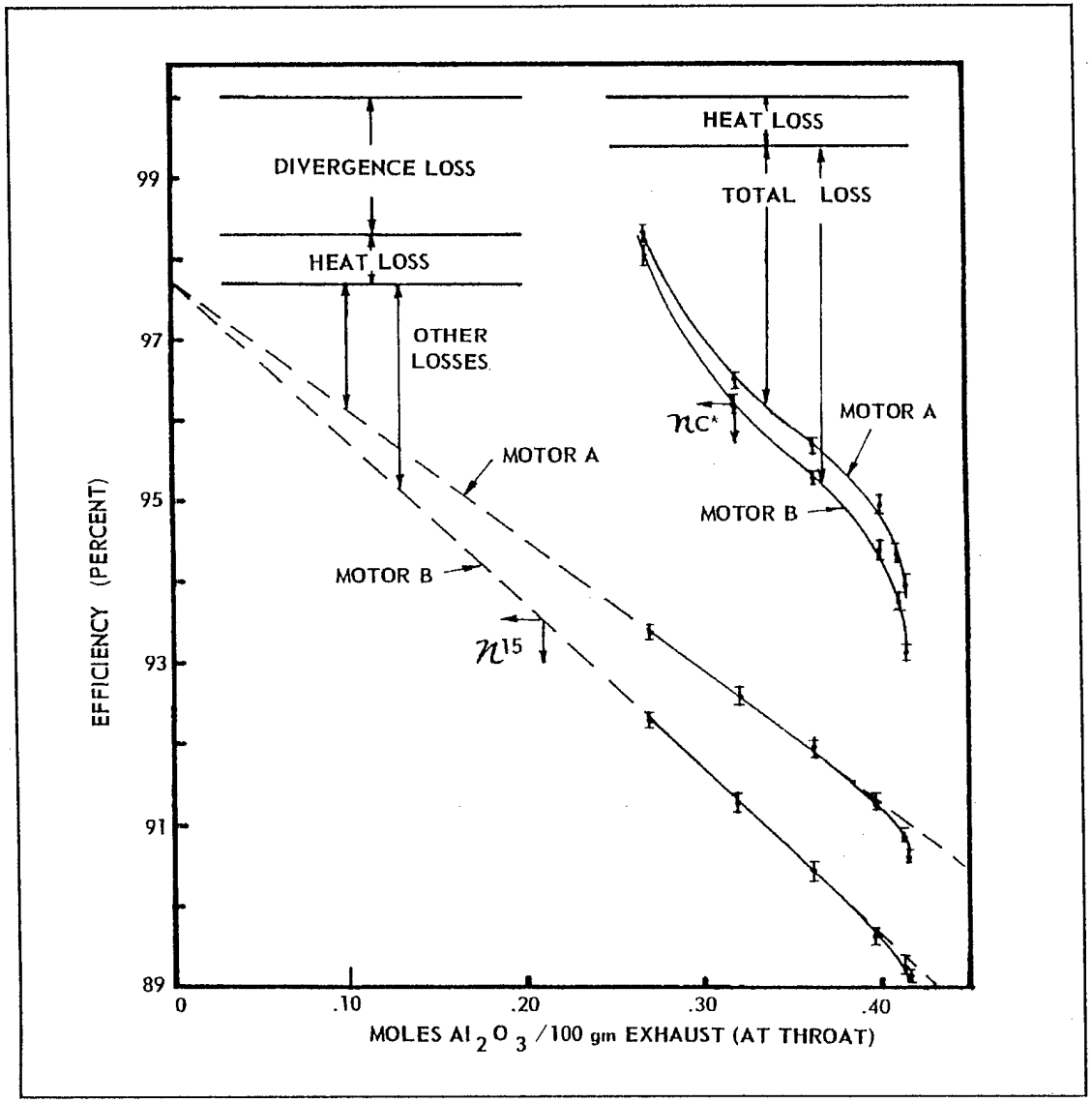
Delivered Isp vs Mass Flow Rate



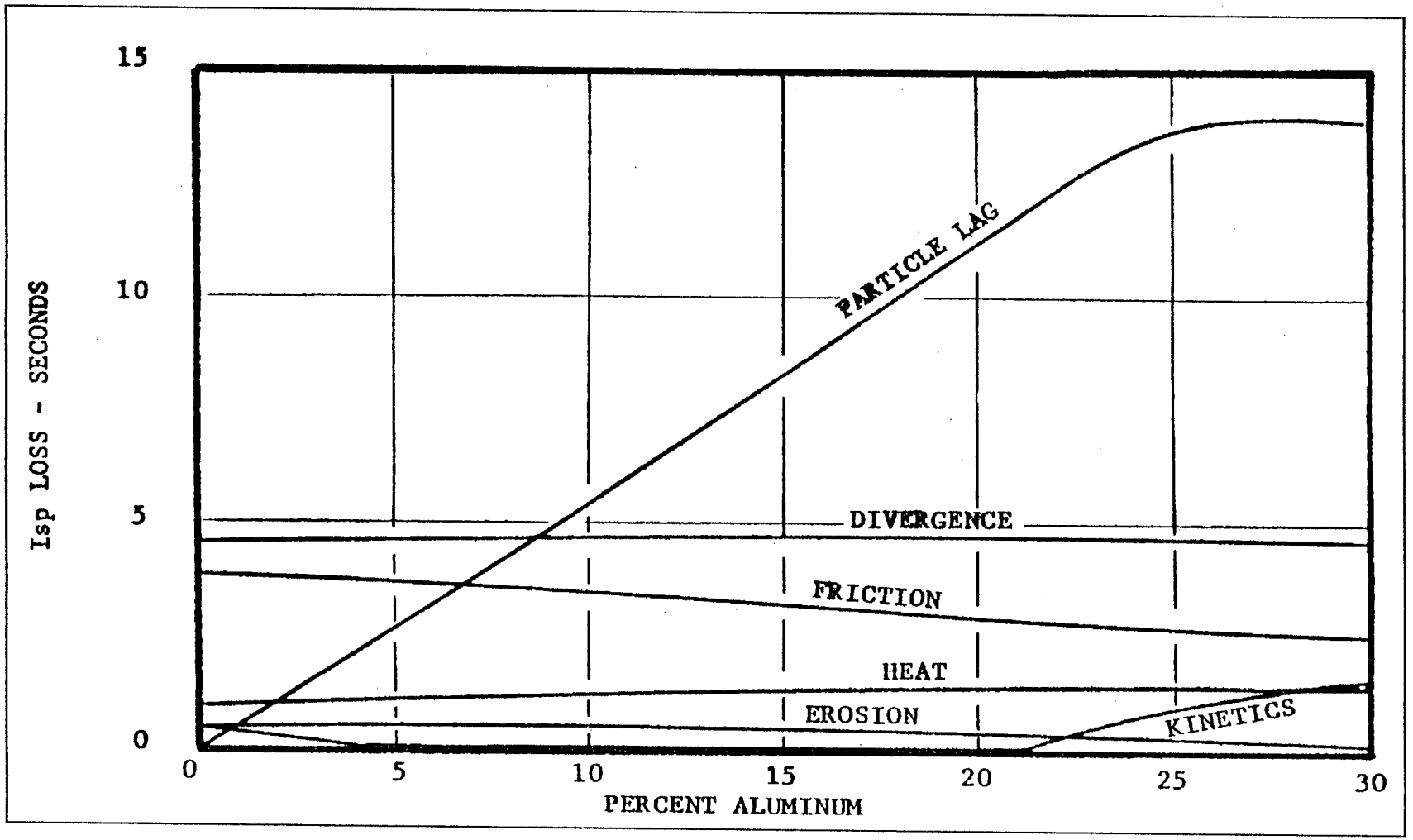
Varying Aluminum Propellant Formulations

Wt% Al	15.	18.	21.	24.	27.	30.
Wt% AP	75.	72.	69.	66.	63.	60.
Wt% HTPB	10.	10.	10.	10.	10.	10.
Rb 1000 psia	0.56	0.55	0.56	0.46	0.51	0.50
η^{15} (ISP)15-lb	92.30	91.27	90.48	89.59	89.11	88.89
η^{15} (ISP)70-lb	93.38	92.84	92.03	91.31	90.92	90.51
Tc(K)@1000psi	3602.	3682.	3746.	3784.	3787.	3743.
T*(K) no Al	2859.	2791.	2705.	2605.	2494.	2376.
Moles/l00 gm. Al_2O_3 at Thrt	0.269	0.319	0.362	0.396	0.413	0.415

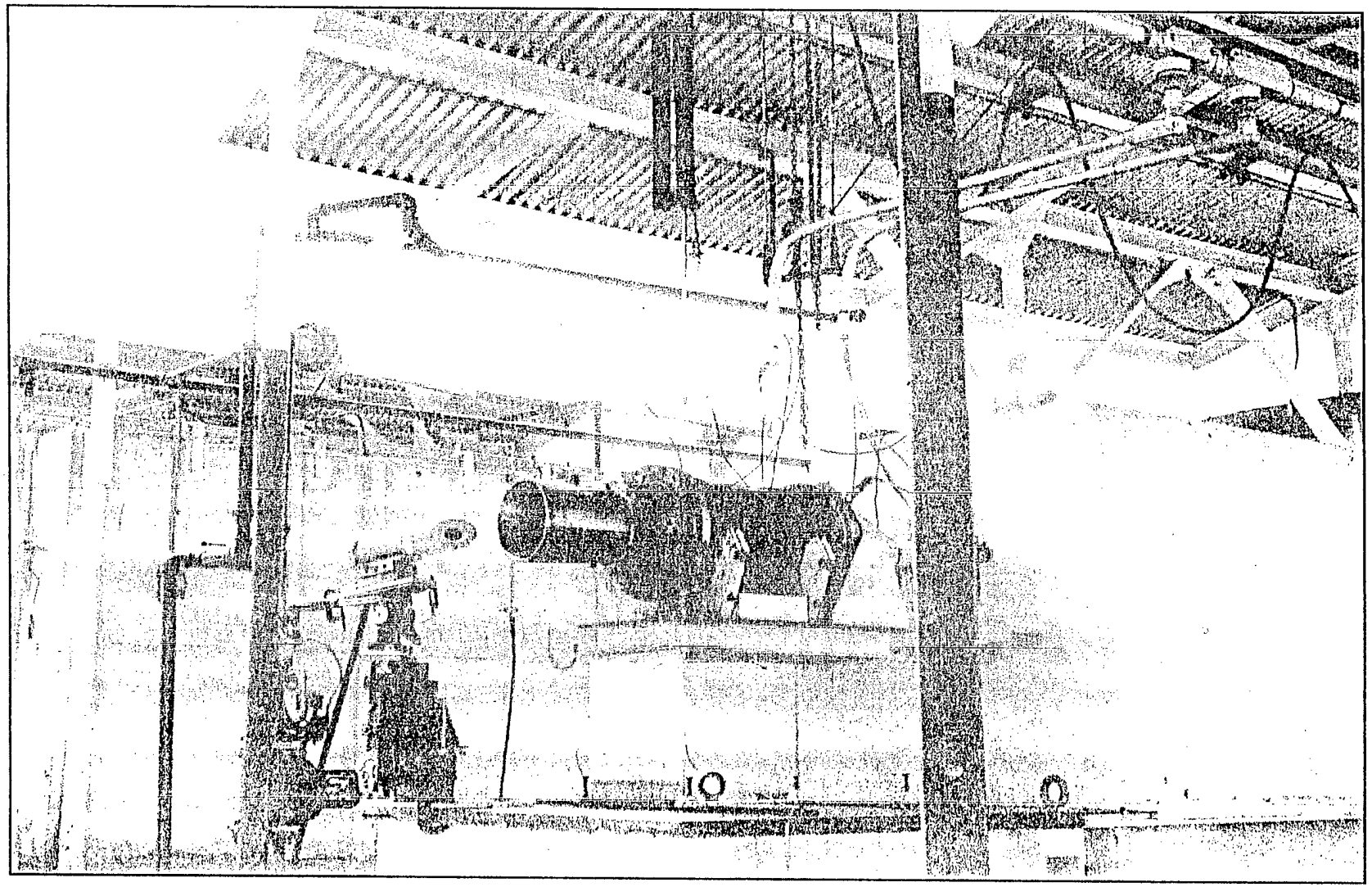
Initial BATES Scaling Approach



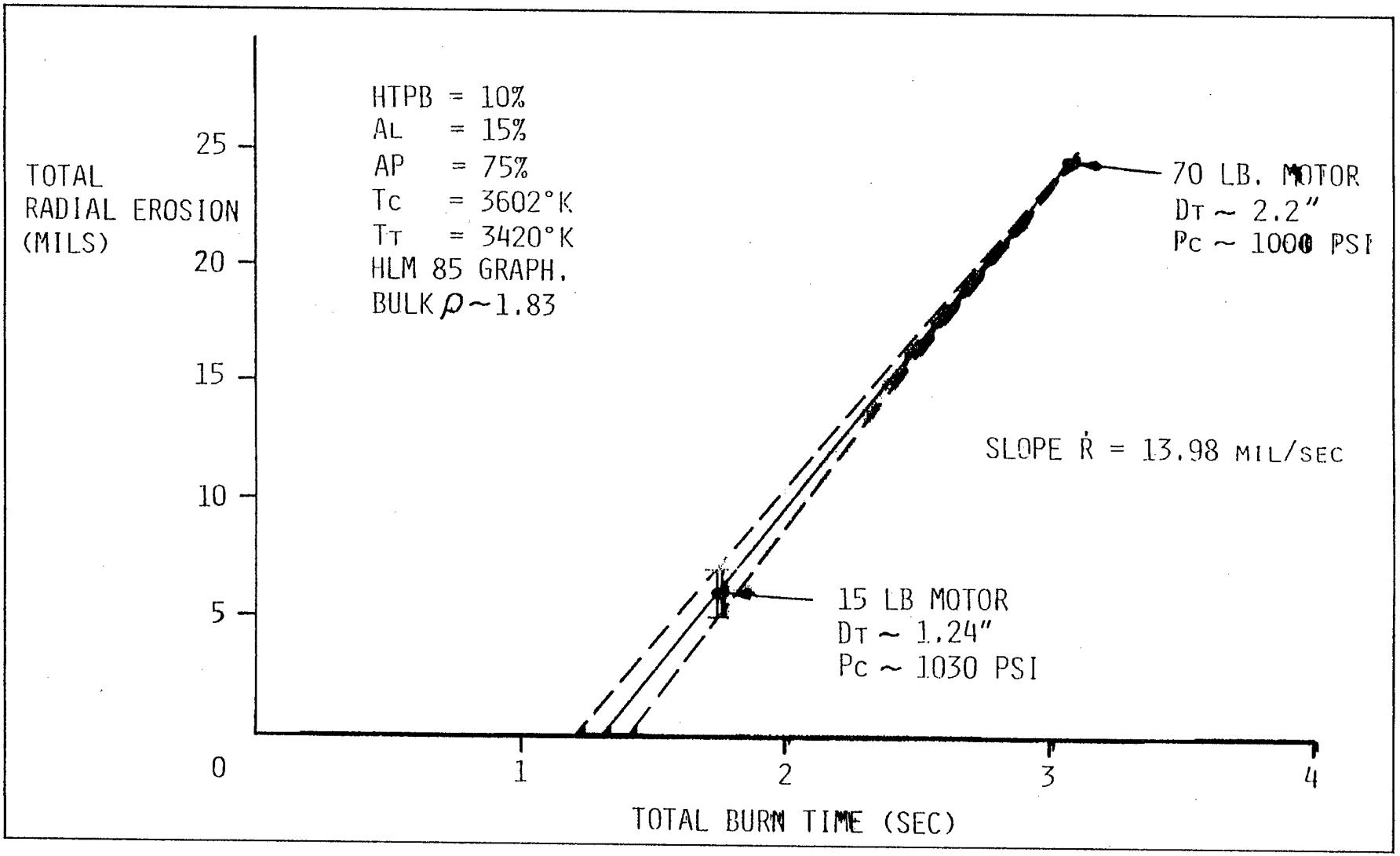
Thrust Losses Occurring in the 70-lb BATES Motor



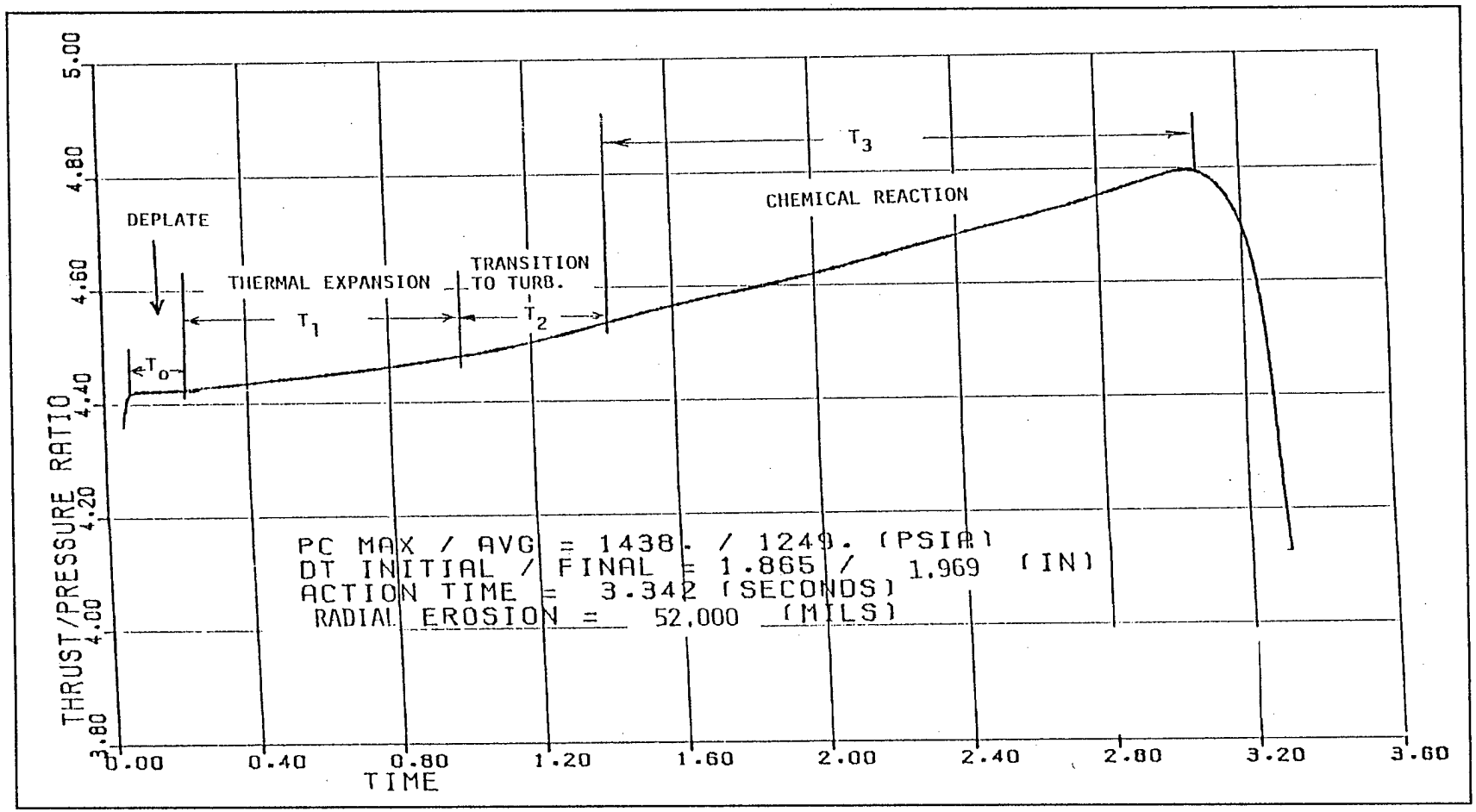
BATES LaserParticle Size Measurements



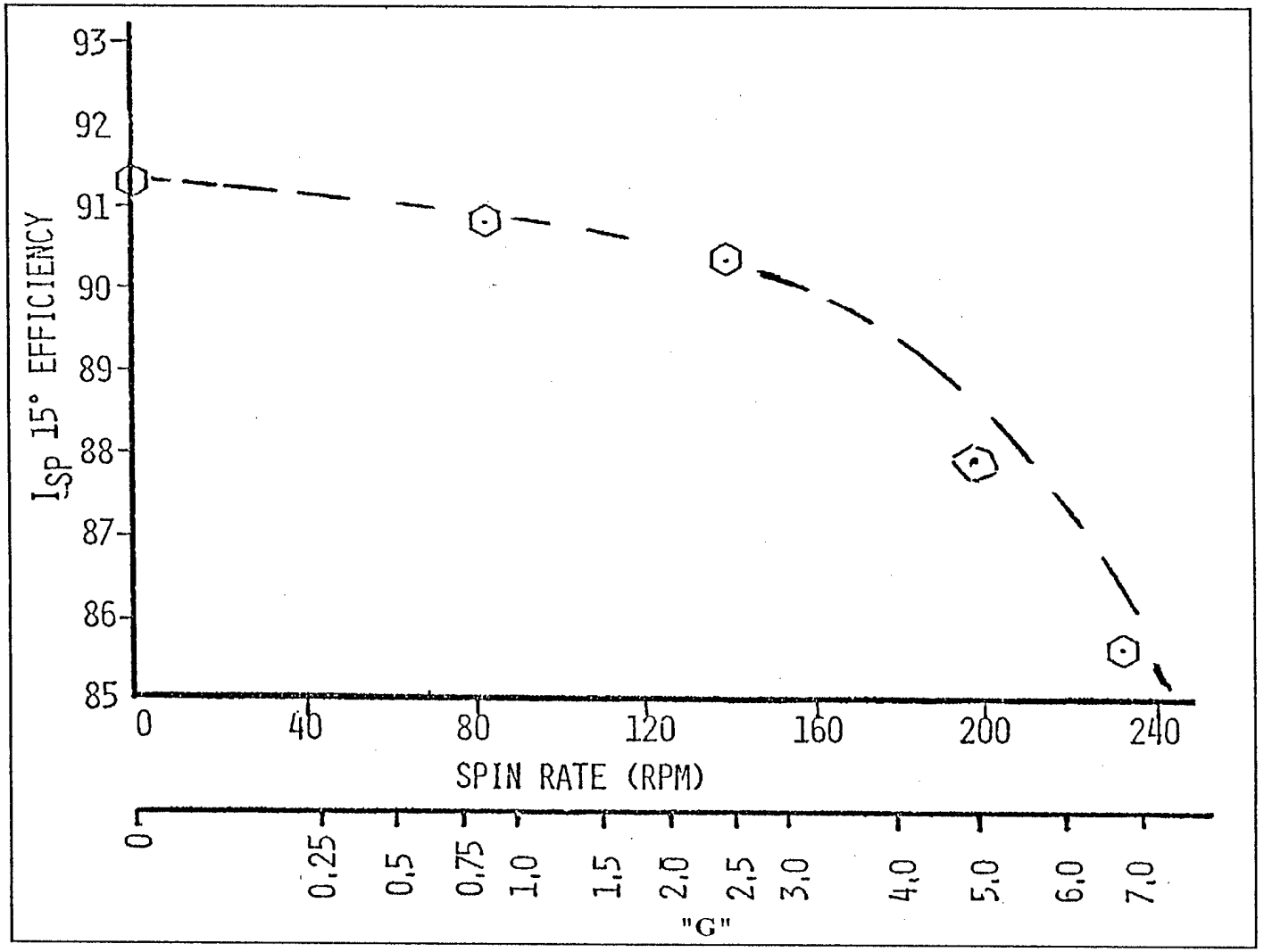
Initial Recession Analysis



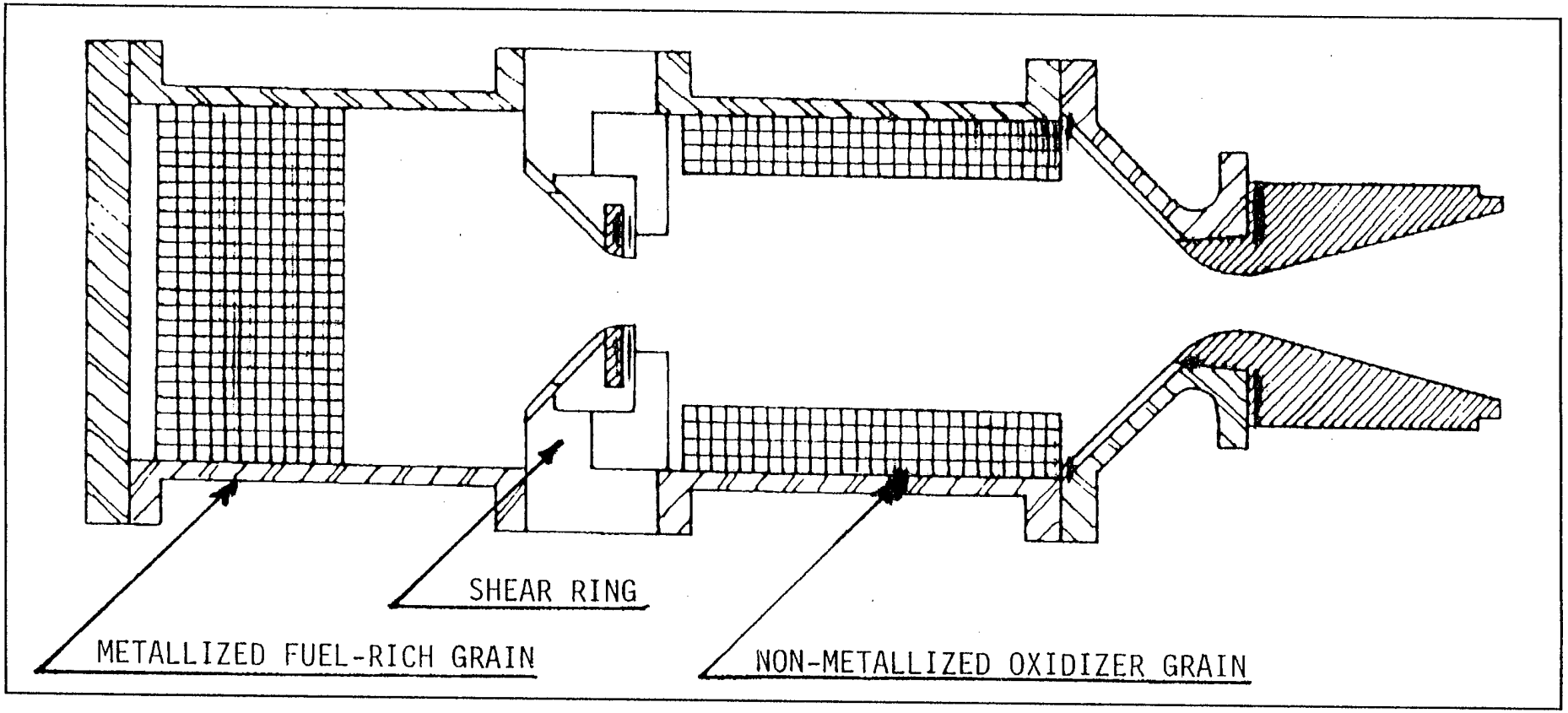
Thrust/Pressure Analysis



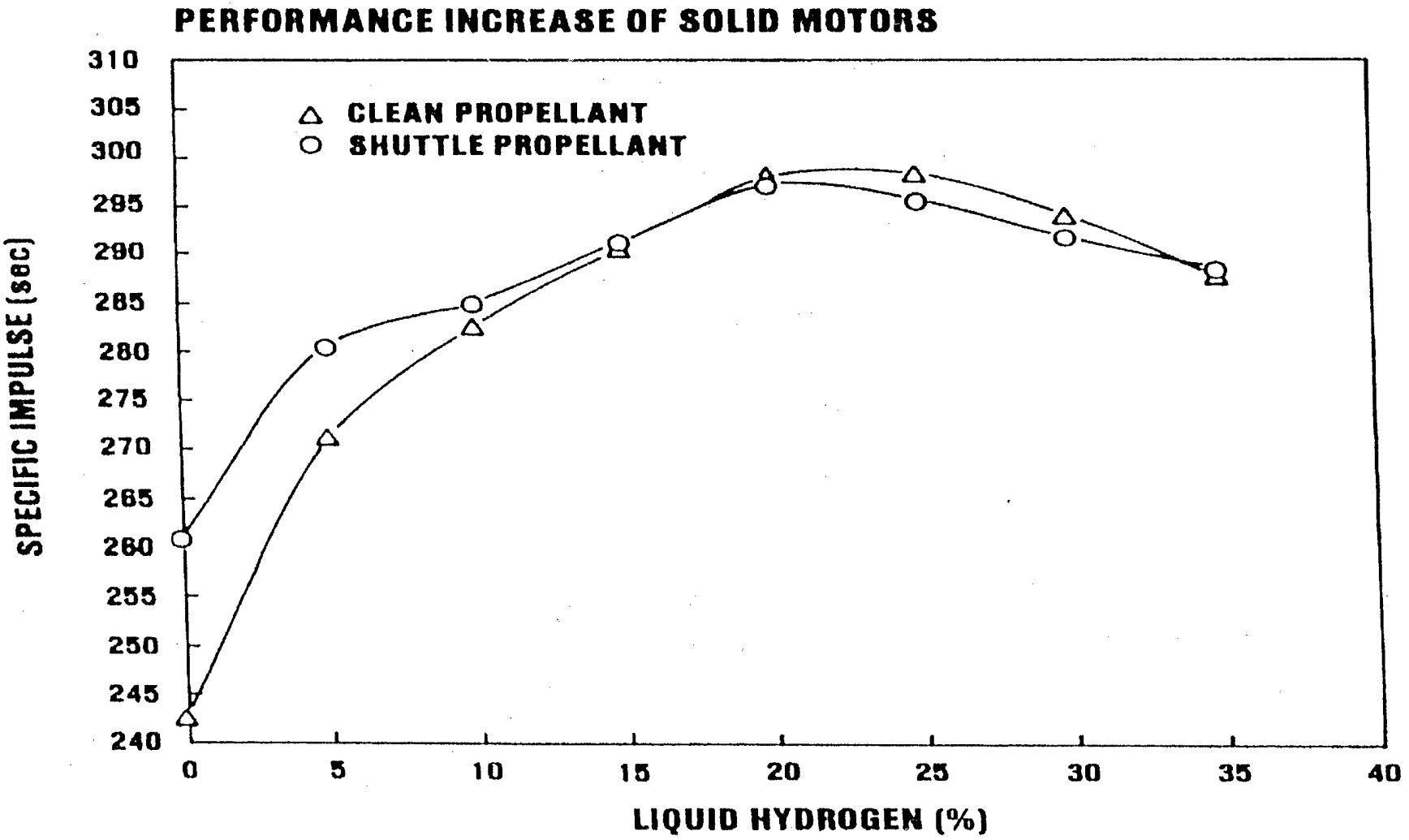
Isp Efficiency Vs Spin "G" Level (70 lb BATES)



Dual Chamber Staged Combustion Feasibility Motor



Performance Increase from Hydrogen Augmentation



Summary

- **BATES is an Invaluable Assessment Tool**
  - Provides Precision Measurements
  - Simple and Analyzable Hardware
  - Adaptable to Tactical, Strategic or Space Needs
    Irreplaceable Propellant and Ballistic Database